Cognition
The AORTA (Stage) Model of Human Performance

- **Attend**
  - attend to selected stimuli
  - attend to one task
  - attend to several tasks

- **Observe**
  - see/read
  - hear
  - feel (palpate)
  - detect
  - discriminate
  - recognize
  - perceive

- **Remember**
  - memorize
  - recall (long-/short-term)
  - remember to do
  - maintain mental model

- **Think**
  - calculate
  - decide
  - solve
  - develop alternatives
  - choose alternative
  - select response

- **Act**
  - reach
  - grasp
  - move/manipulate
  - speak
  - walk/run
  - respond

**Environment**

**Stimuli**

**Responses**
IDEF0 Version of the Stage Model
Attend (Attention)

Attend
- attend to selected stimuli
- attend to one task
- attend to several tasks

Observe

Remember

Think

Act

Environment

stimuli

responses
Attention

- Types of attention (flashlight metaphor)
  - Selective (aim point)
  - Focused (narrow beam)
  - Divided (wide beam)
- Factors influencing selective attention (SEEV theory/model)
  - Salience
  - Effort
  - Expectancy (where info is)
  - Perceived Value
- Attention in
  - perception: stimuli, information channels vs
  - multitasking: tasks
Some Common Human Attentional Fallibilities

- **Attend**
  - Limited attentional resources
  - Attraction to salient but irrelevant cues
  - Inability to focus attention: distraction
  - Inability to divide attention: tunneling

- **Observe**

- **Remember**

- **Think**

- **Act**

Environment

- Fallibility: “ability” to fail, tendency to fail → poor performance (delay, error)
Some Attentional Fallibilities and Countermeasures

● Common Fallibilities
  - limited attentional resources
  - attraction to salient but irrelevant cues
  - inability to focus attention: distraction
  - inability to divide attention: tunneling (often stress-induced)

● Countermeasures
  - Avoid concurrent tasks (multitasking).
  - Limit distractions and interruptions*.
  - Control extraneous environmental stimuli.
  - Match stimulus salience to related task importance/urgency.
  - Reduce stressors (time, environmental, job-related) -- but not all!
  - Provide placeholder cues for complex procedures.
  - Identify critical periods of performance and prohibit distractions.
  - Train operators to be aware of these fallibilities.
Some Attentional Fallibilities and Countermeasures

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  - Provide placeholder cues for complex procedures.
  - Identify critical periods of performance and prohibit distractions.
  - Train operators to be aware of these fallibilities.
Observe
(Sensing + Perception)

- **Observe**: see/read, hear, feel (palpate), detect, discriminate, recognize, perceive
- **Attend**: Environment
- **Remember**: stimuli
- **Think**: responses
- **Act**: Environment

Diagram showing the process of sensory input and response.
Sensing and Perception

- Sensing (cf. Vision, Hearing and Other Senses)
  - Bottom-up processing

- Perception
  - Perceptual Process
    - Analysis
    - Unitization: recognition of patterns
    - Top-down processing: driven by expectations
  - HF Guidelines for Perception
    - Maximize bottom-up processing
    - Maximize automaticity & unitization
      - automaticity: familiar patterns
      - unitization: perception of commonly occurring combinations of features
    - Maximize top-down processing
      - Discriminable features, small vocabulary, context, redundancy, no illusions/confusions
  - Perception tends to be automatic (except when bottom-up processing is poor)
Some Common Human Sensing and Perceptual Fallibilities

- **Attend**
- **Observe**
  - detection thresholds
  - limited visual field
  - sensory impairments
  - auditory masking
  - discrimination thresholds
  - vigilance loss
- **Think**
- **Act**

**Environment**

- **Stimuli**
- **Responses**
Some Sensory and Perceptual Fallibilities and Countermeasures

• Common Fallibilities
  - detection thresholds
  - limited visual field
  - sensory impairments
  - auditory masking
  - discrimination thresholds
  - vigilance loss

• Countermeasures
  - Provide adequate level and quality of illumination.
  - Provide adequate contrast between stimulus and background.
  - Consider visual impairments (esp. presbyopia).
  - Reduce vibration.
  - Design sounds to be in sensitive frequency range (1,000 – 4,000 Hz).
  - Avoid masking by ambient noise and other sounds.
  - continued ...
Some Sensory and Perceptual Fallibilities and Countermeasures (2)

• Common Fallibilities
  - detection thresholds
  - limited visual field
  - sensory impairments
  - auditory masking
  - discrimination thresholds
  - vigilance loss

• Countermeasures
  - Design displays well*.
    • Make displays legible (element size, color, discriminability, ...) or audible.
    • Facilitate redundancy gain.
    • Use discriminable elements.
    • Satisfy principle of pictorial realism.
    • Satisfy principle of the moving part.
    • Minimize information access cost.
    • Provide proximity compatibility.
    • Replace memory with visual information.
  - continued ...
Some Sensory and Perceptual Fallibilities and Countermeasures (2)

• Common Fallibilities
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  - continued ...
Some Sensory and Perceptual Fallibilities and Countermeasures (3)

• **Common Fallibilities**
  - detection thresholds
  - limited visual field
  - sensory impairments
  - auditory masking
  - discrimination thresholds
  - vigilance loss

• **Countermeasures**
  - Design auditory alarms* to be:
    • above background sound,
    • not masked by ambient noise,
    • below danger level,
    • not overly startling (longer rise time),
    • should not interfere with other signals,
    • Informative.
  - continued ...
Some Sensory and Perceptual Fallibilities and Countermeasures (3)

• Common Fallibilities
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  - auditory masking
  - discrimination thresholds
  - vigilance loss

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  - continued ...
Some Sensory and Perceptual Fallibilities and Countermeasures (4)

• Common Fallibilities
  - detection thresholds
  - limited visual field
  - sensory impairments
  - auditory masking
  - discrimination thresholds
  - vigilance loss

• Countermeasures
  - Design text well (typography)*.
    - Use sans-serif font (as opposed to serif font, like this).
    - Use mixed (upper/lower) case.
    - Use adequate font size (> 10 pt).
    - Provide spacing between lines ≥ 25 - 33% overall font size.
    - Use appropriate line length (single-column ~ 4 in, double-column ~ 3 in).
    - Avoid long passages in *italics*.
    - Use *font face* to *emphasize*, *distinguish*, but don't use *too many*.
    - Use dark characters over a light background.
    - Use color coding (highlighting) to emphasize (but not black over dark red, dark green, or dark blue)
Some Sensory and Perceptual Fallibilities and Countermeasures (4)

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Remember
(Working Memory + Long Term Memory)

- Attend
- Observe
- Remember
- Think
- Act

Environment

stimuli

Remember:
- memorize
- recall (long-/short-term)
- remember to do
- maintain mental model

responses
Working Memory

• WM Components
  - Central executive: attentional control & coordination
  - Visio-spatial sketchpad
  - Phonological loop

• WM Limits
  - 7 ± 2 chunks
  - < 20 sec (7 sec ½-life for 3 chunks, 70 sec for 1 chunk)
  - Maintenance rehearsal
  - Confusability, similarity reduce performance
Long Term Memory

- Types of LTM
  - Semantic memory
    - Declarative knowledge (facts)
    - Procedural knowledge (procedures)
  - Event memory (episodic memory)

- Basic Mechanisms
  - Features of knowledge in LTM
    - Strength = f(frequency, recency)
    - Associations (links)
  - WM vs LTM
    - WM as area of activation
    - Role of WM in learning, forming associations
  - Forgetting
    - Low strength
    - weak/few associations
    - Interfering associations
Long Term Memory (continued)

- **LTM Organization**
  - Associative/semantic network (e.g., Forward Observer's knowledge about targeting devices – see next)
    - Schemas: prototypical memory structures
    - Scripts: “typical” activity/event sequences (e.g., restaurant script)
    - Mental model: mental “simulation”
    - Cognitive maps (spatial information, e.g., my “map” of Albany)
- **Episodic memory for events** (see p. 139 ff)
- **Prospective memory**: remembering what to do
- **Situation Awareness**
  - Level I: awareness of objects in environment
  - Level II: comprehension, understanding
  - Level III: prediction of future situation
  - Measurement (e.g., SAGAT = SA Global Assessment Technique)
LTM As Associative Network:
Part of a Forward Observer's knowledge of targeting devices
Some Common Human Memory Fallibilities

- limited working memory capacity (7 ± 2 “chunks”)
- limited working memory duration (< 20 sec)
- inefficient chunking
- verbal/spatial dominance
- weak long-term memory associations
- limited prospective memory

Environment

stimuli

Attend

Observe

Remember

Think

Act

responses
Some Memory Fallibilities and Countermeasures

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  - limited working memory capacity (7 + 2 “chunks”)
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  - inefficient chunking
  - verbal/spatial dominance
  - weak long-term memory associations
  - limited prospective memory

• Countermeasures (Working Memory)
  - Minimize working memory load.
  - Provide placeholders for sequential tasks.
  - Provide other mnemonics*.
  - Exploit chunking.
    - 3-4 characters/chunk (e.g., 1-541-737-2357)
    - Meaningful sequences (e.g., SFO)
    - Letters > digits
    - Digits separate from letters (PQG 929 vs P9Q2G9)
  - Minimize confusability (e.g., 7-2357 [Funk] vs 7-5237 [Helvie])
Some Memory Fallibilities and Countermeasures

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Some Memory Fallibilities and Countermeasures (2)

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  - limited working memory duration (< 20 sec)
  - inefficient chunking
  - verbal/spatial dominance
  - weak long-term memory associations
  - limited prospective memory

• Countermeasures (Long Term Memory)
  - Encourage regular use (↑ frequency, ↑ recency)
  - Encourage active verbalization or active reproduction (repeat, take notes, etc.)
  - Standardize
  - Use memory aids (e.g., GUMPS*)
  - Design information to be remembered:
    • Meaningful
    • Distinctive
    • Well organized
    • “Guessable”
    • Little technical jargon
Some Memory Fallibilities and Countermeasures (2)

• Common Fallibilities
  - limited working memory capacity (7 + 2 “chunks”)
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Gas
Undercarriage
Mixture
Prop(s)
Systems

Also
Undercarriage
Speed
Trim
Airbrakes (glider)
Look
Landing

Photo by P Miller <pmliller@nkn.net>, downloaded 15 Oct 2010 from http://www.tomzap.com/plane.html.
Think
(Decision Making, Problem Solving, Trouble-shooting, ...)

Attend

Observe

Remember

Think
- calculate
- decide
- solve
- develop alternatives
- choose alternative
- select response

Act

Environment

stimuli

responses
Decision Making, Problem Solving, Troubleshooting, etc.

- Decision Making
  - Formulate decision problem
  - Generate alternatives
  - Eliminate alternatives
  - Evaluate alternatives
  - Choose final alternative

- Problem solving: initial state $\rightarrow$ goal state

- Troubleshooting: diagnosis

- Planning and scheduling
  - Command state, predicted state
  - Mental simulation (mental model)
  - Plan continuation error
Some Common Human Decision Making,..., Fallibilities

Attend

Observe

Remember

Think

Act

Environment

- anchoring, confirmation bias
- recency bias
- tendency to treat all sources as equally reliable bias against absence of cues
- asymmetric valuation (gain/loss)
- overconfidence
- erroneous mental model

stimuli

responses
Act (Response)

Attend

Observe

Remember

Think

Act

reach
grasp
move/manipulate
speak
walk/run
respond

Environment

stimuli

responses
Some Common Human Response Fallibilities

- Attend
- Observe
- Remember
- Think
- Act

Environment

Stimuli

- Anthropometric limits
- Neuromuscular limits
- Strength limits
- Response time considerations
- Speed/accuracy tradeoff
Some Action Fallibilities and Countermeasures

- **Common Fallibilities**
  - anthropometric limits
  - neuromuscular limits
  - strength limits
  - response time considerations
  - speed/accuracy tradeoff

- **Countermeasures**
  - Select/design controls for good performance.
    - Use discrete/continuous controls appropriately.
    - Use multi-rotation controls for precise settings, long ranges.
    - Design for movement compatibility (e.g., up/right/CW + down/left/CCW -).
    - Design controls to be easily identified (location, shape, color, type).
    - Do not overburden any one limb.
    - Combine functionally related controls.
    - Consider the least capable user WRT force, speed, accuracy, geometry.
    - Design for natural movement.
    - Keep control movements short.
    - Design for feedback.
    - Design control surfaces to prevent slipping.
    - Provide enough resistance to prevent inadvertent activation.
Some Action Fallibilities and Countermeasures (2)

• Common Fallibilities
  - anthropometric limits
  - neuromuscular limits
  - strength limits
  - response time considerations
  - speed/accuracy tradeoff

• Countermeasures
  - Design workstations for:
    - visibility outside workstation (if appropriate)
    - visibility inside workstation (displays, controls, etc.)
    - accessibility of controls, tools ("let the small person reach")
    - body member support (arm/foot rests, etc.)
    - body member clearance ("let the large person fit")
    - clearance for clothing & personal equipment
    - restraint (if appropriate)
    - protection from injury
    - ease, speed, safety of entry & exit
    - consistency throughout
Metacognition

- Knowledge about knowledge, thinking about thinking
- Attention and timesharing (attention revisited)
  - Selective, focused, divided attention
- Mental effort and resource demand
  - Automatic vs control processing
  - Resource demand
  - Structural similarity
- Task/Attention management
  - Distractions, interruptions
  - “in-situ” distractions, interruptions
  - Task/Attention Management factors
    - Task importance
    - Task status
    - Task urgency
    - Salience of task-related stimuli
Attention In Multitasking

Attention In Multitasking

Attend

Remember

Think

Act

Observe

Environment

stimuli

responses
Attention In Multitasking

- Examples of multitasking
  - driver
  - pilot
  - etc.

- Challenges in multitasking (fallibilities)
  - distractions
  - interruptions
  - reduced performance

- Problems with multitasking: misallocation of attention
  - Driving while talking on cell phone about as risky as driving drunk.
  - 3,154 killed and 424,000 injured in motor vehicle crashes involving distracted drivers in 2013 in US.
  - OSU study of 324 aircraft accident reports: 80 attention errors in 76 (23%) of the accidents.
  - OSU/OHSU surgical simulator study: 8 out of 18 surgeons committed errors when distracted versus 1 out of 18 when not distracted.
Attention As Resource Allocation

Attend: Allocate Mental Resources To Tasks

. . . . . . . Mental resources allocated to various stages of several tasks . . . . . . .

Environment

stimuli

responses
Mental Resources
Multiple Resource Theory (Wickens, 1984)

Sensing & Perception
(AORTA Observe)
Sensory Modalities

Vision (spatial)
Hearing (spatial)
Vestibular senses
Touch
Kinesthesis

Central Processing
(AORTA Remember & Think)
Mental Resources

Analog/Spatial Resources

Categorical/Symbolic/Verbal Resources

Responding
(AORTA Act)
“Effectors”

Hands
Feet
Body

Mouth
Tongue
Concurrent Multitasking

Task A
Task B

Performance

Time

Resources Allocated

To Task A
To Task B

100%
0%
Sequential Multitasking

Task Switching

Task A

Task B

* (distraction)

Task C

* (interruption)

Task D

(incomplete and forgotten ...)

Performance

Time
Countermeasures for Poor Multitasking

• Minimize multitasking
  – eliminate unnecessary tasks
  – shift secondary tasks to lower workload periods
  – declare no-distraction periods
  – reduce job scope

• Additional crew-members
• To-Do Lists / Checklists with placeholders
• Task displays salient in proportion to task priority
  (importance x status x urgency)
• Train primary tasks to proficiency to promote efficient timesharing
• Train operators to manage tasks properly
• Select operators with innate multitasking ability